

SPATIAL ACTIVITIES AT HOME AND THE CRITICAL TRANSITION TO KINDERGARTEN

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In this research we explored the relationship between spatial activities in the home and spatial ability at the start of formal schooling at age four. In total, 30 children participated in this research. Data sources included a demographic questionnaire, a survey of at home spatial activities, and standardized testing in verbal and non-verbal spatial ability. Our results showed that the spatial activities in the home did not predict spatial ability at age four. Gender differences were observed with boys scoring higher in verbal- and non-verbal visual-spatial ability. Given the highly malleable nature of spatial ability and the importance of spatial ability to future STEM-based learning, intentionality in spatial learning by teachers is important.

Key words: Cognition, Early Childhood Education

Introduction

Studies have found that experiences in early childhood have important academic implications for children at the start of schooling and beyond (Alexander & Ignjatovic, 2012). Yet, for both children in early learning settings and those in a home care setting, there may be great variability in the kinds of opportunities for learning (Marope & Kaga, 2015). Expectations for social, emotional, and intellectual engagement may differ significantly. For some children, particularly those in early learning settings, the expectations and routines may not be that vastly different. The differences may be substantial and may even be partially cultural (Brooker, 2010). Consequently, the start of formal schooling is a critical transition for many young children.

Readiness for mathematical learning may be a particularly type of critical transition. Studies report that often relatively little emphasis is placed on mathematics in the home (Blevins-Knabe & Musun-Miller, 1996) or in early learning centers (Early et al., 2005). However, early mathematical ability is related to future success in mathematical learning (Geary, 2011; Sasanguie, De Smedt, Defever, & Reynvoet, 2012). The kinds of activities young children engage prior to formal schooling and in their homes in are linked to future academic outcomes in mathematics (Anders et al., 2012). For example, studies have shown that higher levels of mathematical and spatial talk (Gunderson & Levine, 2011), block play (Hanline, Milton, & Phelps, 2010), and puzzle play (Levine, Ratliff, Huttenlocher, & Cannon, 2012) are related to mathematical ability or spatial ability.

A recent study by Aunio and colleagues (2015) showed that schooling does *not* mediate for lack of prior experience or knowledge, particularly for those children who begin schooling with less basic mathematic understanding than what might be anticipated. Children's (age in months, $M = 74.55$; $SD = 3.50$) number knowledge was tested at three time points during kindergarten. While lower achieving children showed the most gains, children who started school with high mathematical abilities remained high – and higher than those children who tested at medium or low mathematical ability. In short, schooling did not help the lower achieving children catch up to the higher achieving children. This study illustrates the importance of a strong mathematical start and highlights that starting school *is* a critical transition in terms of mathematical learning – albeit perhaps unrecognized by teachers or parents. This research suggests that schools may need to rethink assumptions about a

young child's mathematical-readiness for schooling and how different levels of readiness need to be supported by teachers.

The early mathematics advantage is not exclusively about basic number knowledge. Studies show that spatial ability also has lasting implications for future success in mathematics and even in participation in STEM-based disciplines (Lubinski, 2010; Wai, Lubinski, & Benbow, 2009). Gunderson and colleagues (2012) found that spatial ability at age five contributed to level of number knowledge at age eight. Moreover, spatial skills in kindergarten have been found to be a more powerful predictor of mathematics ability in grades one and two than even mathematics skills in kindergarten (Frick, Möhring, & Newcombe, 2015). Childhood spatial activities are linked to spatial skills and mathematics grades in adulthood (Doyle, Voyer, & Cherney, 2012).

Spatial ability is defined broadly as the understanding of relations about (i.e., properties and attributes) and between objects and spaces including transformations in either two or multiple dimensions (i.e., mental rotations) (Clements, 2004; Linn & Peterson, 1985). Often spatial ability is associated synonymously with "visual-spatial ability." That is the case with our use of the term and that is clear in our choice of standardized tests described shortly.

In this research we look specifically at the spatial activities of four-year-old children and how the types of activities/toys children engage with intersects with spatial ability at the start of kindergarten. Our research questions were as follows: (1) *What are the sorts of spatial activities four year olds children engage in, as reported by their parents?* (2) *Do these activities contribute to children's spatial ability at the start of formal schooling in kindergarten?*

Given that approximately 60% of young children are cared for at home (Barnett, Carolan, Fitzgerald, & Squires, 2012), we analyze our results further by considering whether early childhood education and care is connected to the experiences reported by parents and spatial ability at the start of formal schooling. We also analyze our results by gender because of the numerous studies that report a gender advantage to boys in spatial ability (Frick et al., 2015; Linn & Peterson, 1985).

In our jurisdiction age four represents the start of formal schooling with a full-day kindergarten program and thus this age is the critical transition point between home and school or early learning/childcare setting and school for these young children. Given the highly malleable nature of spatial ability (Uttal et al., 2013), an understanding of how home environments contribute to the development of spatial ability is important to subsequent spatial ability but also to future mathematics learning.

Recent research exploring spatial ability in girls (approximate age 6) by Dearing and colleagues (2012) found that home spatial activities were related to the girls' spatial skills but not proximal predictors of spatial skills. Other recent research using longitudinal data found that spatial activities in the home of children age four to seven, were predictive of spatial ability when tested on the Block Design subtest from the WPPSI-IV (Frick et al., 2015). This research also found a gender difference with boys engaging more in spatial activities than boys. In our research, we consider whether the same trends observed in these other studies are evident at age four and whether these trends hold true for boys and girls. Moreover, we consider both non-verbal and verbal measures of spatial ability (cf. Block Design used by Frick et al., 2015) and a wider range of proposed spatial activities.

The theoretical framework for this research is *critical praxis*. Drawn from Tilleczeck (2012), critical praxis "denotes critique and interrogation of the theory and practice surrounding childhood transitions" (p. 13). The objective of the critical praxis is to enhance the experiences of young children by inspiring "schools and people to function as communities which build bridges between students, parents, teachers, and communities" (Tilleczeck, 2012, p. 17). In the present research, theory intersects practice through an analysis of the juxtaposition of home practices against young children's spatial ability as a possible precursor for future spatial learning in a school setting.

Methods

Participants

Thirty junior kindergarten children ($M_{\text{age}} = 49.9$ months; $SD = 3.2$; $\text{Range} = 45$ to 56 months; 19 males) were recruited from six classrooms within one elementary school. While mandatory schooling begins in grade one, or age six, full day schooling is available for all children starting at age four. Out of the 30 children, 27 parents (23 mothers, 4 fathers) participated in the parental portion of the study. The other three parents chose to not complete any of the questionnaires and thus these children were removed from the study. The available demographic data for the 27 participants indicated that English was the most frequent language spoken at home for all children. The socioeconomic status (SES) of the participants was determined by using mother's highest education level (Catts, Fey, Zhang, & Tomblin, 2001). The highest education level attained by mothers was as follows: 4% completed some high school, 19% high school, 30% college/trade, 41% university, and 7% completed graduate/professional education.

Procedure

Children's visual-spatial ability was assessed by the Stanford Binet Intelligence Scales for Early Childhood, Fifth Edition (SB5; Roid, 2003). The children were administered the SB5 in the school library. Each child was assessed one-on-one by either the second author or a trained research assistant. The study also consisted of a parental portion, in which parents were asked to complete a demographics questionnaire, and an at-home spatial activities questionnaire (Dearing et al., 2012).

Stanford Binet Intelligence Scales for Early Childhood, Fifth Edition (SB5; Roid, 2003).

The children were administered both the Nonverbal and Verbal Visual-Spatial Processing subtests from the SB5. Age normed scaled scores ($M = 10$, $SD = 3$) were calculated for each subtest. The Nonverbal subtest includes 16 items and requires the child to fit shapes and combine shapes into a plastic board that has forms of shapes cut out in it. These items measure the child's visualization ability of visual-spatial processing. For the last eight questions on the Nonverbal subtest, the children are presented with a two-dimensional image and are required to recreate that image with three-dimensional geometric figures. The Verbal Visual-Spatial Processing (Position and Direction) subtest is comprised of 12 items. The Verbal subtest evaluates children's understanding of position and direction by following verbal instructions and moving objects into the certain positions. The child is presented with an image and is asked to place a block on a certain direction or position with relation to the image.

Demographic Questionnaire. The participating parent completed a demographic questionnaire indicating their child's gender, date of birth, the language most frequently spoken at home, their relationship to the child, mother's highest education level, and how many hours the child spent in child care from ages one to three. Children were grouped into low (college and under) or high (university and above) SES groups.

Child Spatial Activities Questionnaire. The spatial activities questionnaire was adopted from Dearing and colleagues (2012) and it measures the frequency of children's engagement in spatial activities and toys at home. The spatial activities questionnaire (Cronbach's Alpha = .85) has good reliability (Dearing et al., 2012). Parents were asked how often their child engages in 20 spatial activities (e.g., builds with construction toys such as building blocks, LEGO®, and magnet sets). The parents indicated the frequency of each activity on a five-point scale (1 = *never*, 2 = *seldom*, 3 = *occasionally / a couple times per month*, 4 = *often/weekly*, 5 = *many times per week*). An average was computed in order to obtain an average frequency score for the spatial activities. Children were also grouped into either a high and low spatial activity group based on the average median cut-off.

Results and Discussion

We examined the types of spatial activities parents engage in with their child. The most frequently occurring spatial activities were as follows: playing in parks, playing with action figures or cars, colouring, painting, or drawing free hand, and building with construction toys. Parents also indicated that play with blocks and puzzles also occurred often or weekly (See Table 1 for mean frequencies of each activity).

Table 1: Spatial Activities Engaged in at Home

Spatial Activity	Mean (<i>SD</i>)	Min – Max
1. Play in parks or green spaces when the weather permits	4.7 (.52)	3 – 5
2. Play with toy soldiers, action figures, cars/trucks, planes or trains	4.4 (.89)	2 – 5
3. Colour, paint, or draw free hand (not filling-in outlines)	4.3 (.86)	2 – 5
4. Build with construction toys (such as building blocks, Legos, magnet sets)	4.2 (.65)	3 – 5
5. Set up play environments with toy furniture, toy buildings, train tracks or building blocks	4.1 (.81)	2 – 5
6. Play with puzzles (such as picture puzzles, tangrams, slide puzzles, 3-D puzzles)	4.1 (.84)	2 – 5
7. Race toy animals or cars on the ground or around obstacles	4.1 (.84)	3 – 5
8. Do arts and crafts projects	4.0 (.78)	2 – 5
9. Explore woods, streams, ponds, or beaches or search for plants, bugs, or animals outdoors when the weather permits	3.7 (.76)	2 – 5
10. Use a computer/video games to do drawing, painting or matching and playing with shapes	3.7 (.90)	2 – 5
11. Play paper and pencil games (such as mazes, connect-the-dots)	3.3 (1.1)	1 – 5
12. Set up obstacle courses, tunnels, or runways for kids or pets	2.8 (1.0)	1 – 5
13. Build dams, forts, tree houses, snow tunnels, or other structures outdoors when the weather permits	2.8 (1.1)	1 – 5
14. Use tools (such as hammers or screwdrivers) to make things or take things apart to see how they work	2.7 (1.3)	1 – 5
15. Play with flying toys (such as kites, paper airplanes)	2.5 (.8)	1 – 4
16. Fold or cut paper to make 3-d objects (such as origami, paper airplanes)	2.5 (1.1)	1 – 4
17. Climb trees when weather permits	2.1 (1.2)	1 – 5
18. Draw maps (such as treasure hunt maps)	2.0 (1.1)	1 – 5
19. Draw plans for houses, forts, castles or other buildings or layouts	1.8 (1.2)	1 – 5
20. Use kits to build models (such as airplanes, animals, dinosaurs, doll houses)	1.7 (.65)	1 – 3

Note. Mean frequency and minimum and maximum for each spatial activity. Parents indicated the frequency of each activity on a five-point scale (1 = never, 2 = seldom, 3 = occasionally /a couple times per month, 4 = often/weekly, 5 = many times per week).

Children were grouped into high- and low-frequency of spatial activity groups. There were 14 children in the low spatial activity group and 13 were in the high spatial activity group (*Range* = 2.05 to 4.15, *Median* = 3.40). Children in the high spatial activity group had higher scores on their nonverbal visual-spatial ability; however, children in the low and high spatial activity group had similar scores for their verbal visual-spatial ability (See Table 2 for means). This research did not explore actual levels of spatial talk in the home which have been found to be related to spatial thinking (Gunderson & Levine, 2011). This may have explained the lack of differences between the groups.

Table 2: High- and Low-frequency Spatial Activity Groups

Spatial Task	Spatial Activity Group		Years in Child Care			
	Low	High	0	1	2	3
Nonverbal Mean (<i>SD</i>)	11 (3.1)	12.2(3.8)	9.5(6.3)	10.7(2.8)	11.5(4.3)	12.5(3.1)
Verbal Mean (<i>SD</i>)	12.3 (2.6)	12.2 (2.6)	12.5(0.7)	11.7(2.4)	11.6(3.4)	12.9(2.5)

Note. Mean scaled scores and standard deviations for nonverbal and verbal visual-spatial ability examining high and low spatial activity groups and years in child care.

We also examined whether attending child care prior to entering formal schooling influenced children's spatial abilities. There were two children that never attended child care, seven children attended for one year, six children for two years, and 12 children attended child care for three years. During the first three years of life every additional year spent in child care showed an increase in their average nonverbal visual-spatial ability (See Table 2 for means). In terms of verbal spatial ability there was not an evident pattern of increase based on years spent in child care, however children who attended child care for all three years had the highest scores (See Table 2). This would be expected given the many studies that report that early childhood education, particularly that of a higher quality, can have important implications for future academic outcomes (Alexander & Ignjatovic, 2012).

We found that boys ($M = 11.79$, $SD = 3.6$) had higher nonverbal visual-spatial scores compared to girls ($M = 10.45$, $SD = 3.5$). Girls ($M = 12.36$, $SD = 3.1$) had slightly higher verbal visual-spatial scores compared to boys ($M = 12.16$, $SD = 2.6$). Boys and girls frequency of spatial activities were also compared. Boys ($M = 3.4$, $SD = 0.4$) and girls ($M = 3.16$, $SD = 0.4$) had similar mean frequencies, with boys showing a slightly higher frequency. A Mann-Whitney test showed this to be a non-significant difference ($U = 46.7$, $p = .08$). Parental reports of higher frequency of spatial activity in boys is consistent with reported results (Frick et al., 2015).

Correlations were conducted for nonverbal and verbal visual-spatial ability between the following factors: gender, SES, child care attendance, and at home spatial activity average. There were no significant correlations ($p > .05$). There was also no correlation between nonverbal and verbal visual-spatial ability, therefore indicating that doing better on one subtest did not mean children were more likely to do better on the other subtest.

To examine if there were any significant effects or interactions between spatial activities, child care attendance, SES and gender a 4 (child care: 0 years vs. 1. vs. 2 vs. 3) x 2 (spatial group: low vs. high) x 2 (SES: low vs. high) x 2 (gender: boys vs. girls) Analysis of Variance (ANOVA) with nonverbal visual-spatial ability as the dependent variable was conducted and revealed no significant main effects or interactions ($p > .05$).

The same ANOVA was conducted with verbal visual-spatial ability as the dependent variable. There were also no significant effects or interactions for verbal visual-spatial ability ($p > .05$). Similar to Dearing and colleague's research (2012), spatial activities were not predictors of spatial ability girls but also boys. Dearing et al.'s research considered six year olds. Our research provides further evidence. Different than Dearing et al. is that we did not find any correlations between the spatial activities and spatial ability.

The lack of significant findings could be explained by the low sample of children across groups. This is recognizably a limitation of this research. However, there are other possible explanations. Frick and colleagues (2015) recently reported that spatial activities in the home at age five were related to spatial ability at age eight. According to Uttal and colleagues (2013), spatial ability is highly malleable and thus children in Frick et al.'s study likely benefited from formal school instruction or a malleability effect. Additionally, the higher levels of spatial play that were reported by parents may not have been sufficiently complex for the child to move the child along in their continuum of learning (Gregory, Kim, & Whiren, 2003; Hanline et al., 2010; Lee, Kotsopoulos, & Zambrzycka, 2013). Finally, parents' perception of a "high" level may vary – despite the Likert scale qualifiers. Some naturalistic observational data would be helpful to offset self-reports on such frequencies, as well as larger sample sizes.

Conclusions and Educational Implications

Research has shown that spatial skills are important for future success in both mathematics and in STEM-based disciplines (Lubinski, 2010; Newcombe, 2010; Tolar, Lederberg, & Fletcher, 2009; Wai et al., 2009). Understanding the degree to which children's spatial ability is developed at the start of formal schooling and the kinds of activities in the home environment that contribute to the development are important. The results from the present research suggest that home activities are not necessarily mapping directly onto spatial ability at the start of formal schooling. These results have important implications for teachers – and perhaps lasting implications for children. Schooling itself does not contribute to mathematical resilience in the absence of intentionality (Aunio et al., 2015). A lack of intentionality may be even more problematic for spatial ability. Recent research reports that relatively little time is spent overall on spatial ability (or geometry) in schools compared to other curricular strands such as numbers, data management, and measurement (Mullis, Martin, Foy, & Arora, 2012; Organisation for Economic Co-operation and Development, 2012). Consequently, intentionality in nurturing spatial ability is important.

Such intentionality would involve having a clear understanding of the beginning points of the child's spatial understanding and then building pedagogical moments to advance the child's understanding based on their unique starting point. Teachers may be challenged in determining the starting point because early mathematical development, including the development of spatial ability, may be underemphasized in their professional training. Future research should explore the ways in which professional programming prepares future teachers and early childhood educators to understand early spatial and mathematical development.

From a critical praxis perspective, the importance of occasioning spatial learning and in fostering a deeper understanding of spatial learning amongst teachers should be evident. By linking the home-school connections, the potential for enhancing opportunities for learning are increased. In the case of spatial ability and even mathematical ability, the need to occasion such bridges is paramount given the clear research that shows an academic advantage to those young children that come to school

knowing more mathematical concepts (Aunio et al., 2015; Geary, Hoard, Nugent, & Bailey, 2013; Romano, Babchishin, Pagani, & Kohen, 2010).

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